AD-A062 645 NAVAL RESEARCH LAB WASHINGTON D C F/G 4/1

COMPARISON OF LOW- AND HIGH-RESOLUTION INFRARED PROPAGATION MEA--ETC(U)

NOV 78 K M HAUGHT, J A CURCIO, J A DOWLING

UNCLASSIFIED NRL-8254 NL

1 OF 1
ADA
062645

END
DATE
FILMED
3-79
DDC

NRL Report 8254

Comparison of Low- and High-Resolution Infrared Propagation Measurements in the 3- to 5-μm Atmospheric Window

K. M. Haught, J. A. Curcio, J. A. Dowling,
D. H. Garcia, C. O. Gott, S. T. Hanley,
R. F. Horton, J. T. Ulrich, and J. L. Walsh

Naval Research Laboratory

R. J. Bergemann and M. C. Sola

Army Night Vision and Electro-Optics Laboratory

R. E. Roberts
Institute for Defense Analyses

November 9, 1978

NAVAL RESEARCH LABORATORY
Washington, D.C.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

14

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
NRL R[redacted]t 8254

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

9

4. TITLE (and Subtitle)

6

COMPARISON OF LOW- AND HIGH-RESOLUTION INFRARED PROPAGATION MEASUREMENTS IN THE 3- TO 5-~~μm~~ ATMOSPHERIC WINDOW.

micrometers

5. TYPE OF REPORT & PERIOD COVERED
Interim report ~~on a continuing~~ NRL problem

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)

10

K. M. Haught, J. A. Curcio, J. A. Dowling, D. H. Garcia, C. O. Gott, S. T. Hanley, R. F. Horton, J. T. Ulrich, J. L. Walsh, R. J. Bergemann, M. C. Sola, R. E. Roberts

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Optical Sciences Division
Naval Research Laboratory
Washington, D.C. 20375

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
NRL Problem N03-28
Program Element 62332N
Project SF32344017

11. CONTROLLING OFFICE NAME AND ADDRESS
Optical Signatures Program
Naval Weapons Center
China Lake, CA 93555

11 9

12. REPORT DATE
Nov[redacted]978

13. NUMBER OF PAGES
15

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

12 16p.

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

16 F32344

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

17 SF32344Ø17

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Atmospheric transmission
Fourier-transform spectroscopy
Infrared absorption
Radiometry

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A field experiment designed to compare the measurement performance of a laser-calibrated, high-resolution spectroscopic system with that of a low-resolution transmissometer/radiometer system has been carried out along a 5-km range.

We compared the results of the two measurements by numerically convolving the high-resolution transmission data with the spectral-response characteristics of the transmissometer system.

(Continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

251 95Ø

B

20. ABSTRACT (Continued)

For the limited range of meteorological conditions under which these measurements were made, the standard deviation of the transmittances measured by these two techniques is 0.06.

CONTENTS

COMPARISON OF LOW- AND HIGH-RESOLUTION INFRARED PROPAGATION MEASUREMENTS IN THE 3- TO 5-μm ATMOSPHERIC WINDOW

INTRODUCTION

In September 1976 the Infrared Mobile Optical Radiation Laboratory (IMORL) of the Naval Research Laboratory successfully combined high-resolution, Fourier-transform spectroscopy (FTS) with previously developed techniques for measuring laser extinction along 5-km, sea-level paths [1,2]. This significant advance in precision atmospheric spectroscopy provided a useful reference for comparison with other electro-optical instrumentation designed to measure infrared transmission of the atmosphere.

In November 1976 a coordinated atmospheric-transmission-measurement experiment was carried out with the IMORL facility and a transmissometer/radiometer system operated by the Army Night Vision Laboratory. These measurements were made at the Naval Air Station, Patuxent River, Maryland, over a 5.1-km range along the western shore of the Chesapeake Bay. A preliminary account of this work was reported earlier [3].

EXPERIMENTAL PROCEDURES

The high-resolution (0.08 cm^{-1}) measurements utilized a Fourier-transform interferometer-spectrometer system manufactured by Carson-Alexiou Corporation. The 90-cm-diameter IMORL transmitter telescope projects the radiation from either blackbody or laser sources across the experimental path. The 120-cm-diameter IMORL receiver telescope directs the collected signal to a detector/integrator for the laser-extinction measurements or to the interferometer for the FTS measurements. Radiometric calibration of the high-resolution spectra was based on laser-extinction measurements made with both DF and CO lasers [1,2,4].

The low-resolution measurements were obtained with a transmissometer system manufactured by Barnes Engineering Company [5]. The transmitter unit of this double-ended system modulates and projects the beam from a 1273-K blackbody source across the experimental path. A 10-cm-diameter collector in the receiver unit focuses the collected signal through any of 18 selectable filters onto a cooled InSb detector. Radiometric calibration of the received signals is based on zero-range measurements made with a 200-μm pinhole placed in the optical path of the transmitter.

To facilitate a comparison between the high-resolution FTS measurements and the low-resolution transmissometer measurements, the FTS system was also used to measure the spectral response of the 15 transmissometer filters employed in the experiment. The resolution of the FTS-measured atmospheric-transmission spectra was then degraded to match that of each filter. We evaluated these convolution integrals by summing for each point in the high-resolution spectra (every 0.06 cm^{-1}) the product of the FTS-measured atmospheric transmission, the spectral emissivity (in photons) of a 1273-K blackbody,

Manuscript submitted June 21, 1978.

the spectral response of the transmissometer system, and the response of each transmissometer filter.

RESULTS

A sample of these measurements has been compared with the predictions of atmospheric propagation codes [6]; however, such comparisons are beyond the scope of this report. Detailed comparisons of laser-calibrated FTS spectra with HITRAN and LOWTRAN calculations appear elsewhere [1,7].

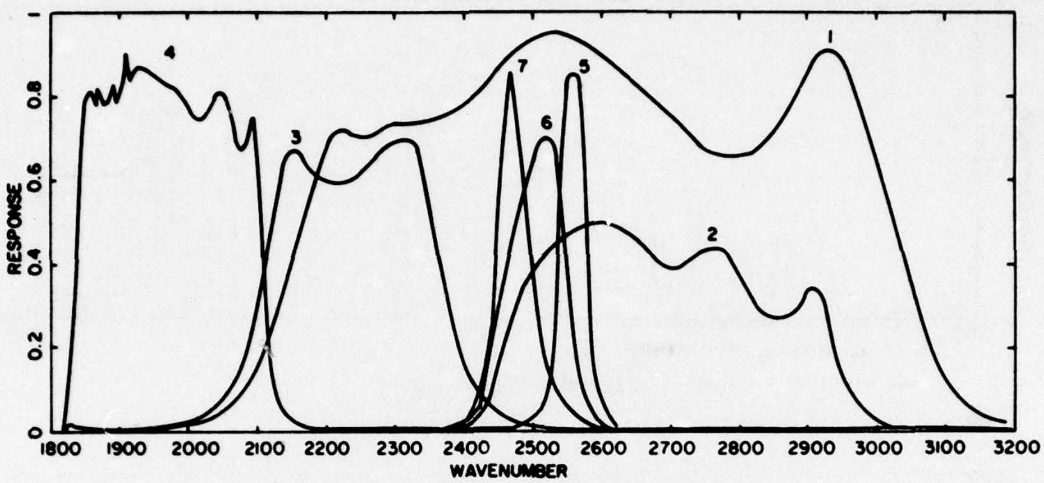
Figures 1a and 1b show the relative-response functions of the 15 transmissometer filters. Figures 2a through 2f present the high-resolution FTS spectrum for one of the periods during which the combined measurements were made, and Fig. 3 presents a comparison of the high-resolution and low-resolution measurements for the same period.

Tables 1 through 5 provide listings of the low-resolution results and the filter-convolved, high-resolution measurements for each of the five periods during which the combined measurements were made. The footnotes summarize the meteorological data recorded for these times.

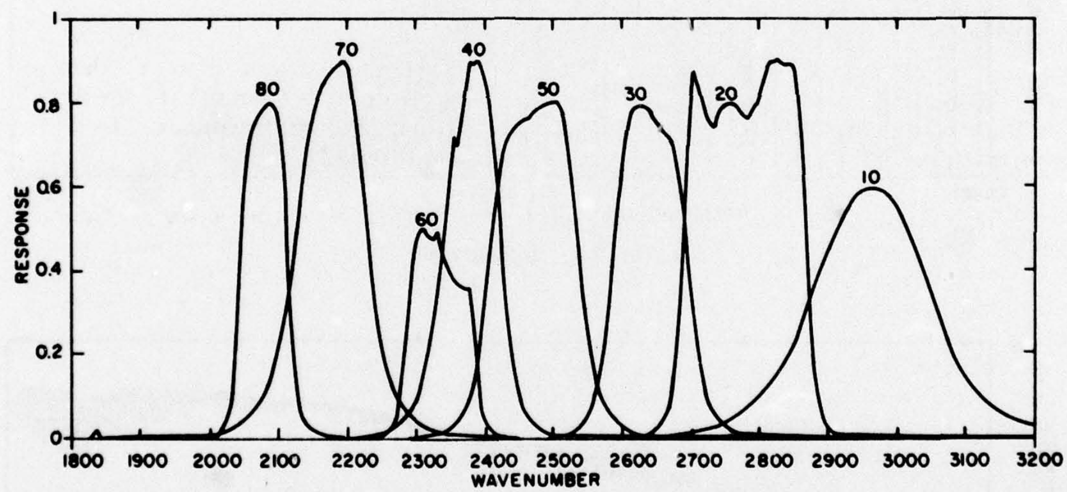
Figure 4 is a "scatter plot" comparing the atmospheric transmittance measurements derived by the high-resolution FTS technique with the low-resolution results obtained from the transmissometer. As indicated by the legend, the different symbols represent data for different transmissometer filters. The line in Fig. 4 shows a least-squares fit to the data. The slope of this line is 0.985, the intercept is 0.038, the standard deviation of the data from the fit is 0.055, and the coefficient of correlation is 0.95.

The transmissometer measurements tend to show higher atmospheric transmittances than do those made by the FTS/laser technique. As the data presented in Tables 1 through 5 show, for 48 of the 74 measurements the transmissometer measures a transmittance that is within 0.05 of that obtained with the FTS system, for 14 of the 74 measurements (19%) the transmittances agree to within 0.05 to 0.10, and for the remaining 12 measurements (16%) the two types of measurement techniques result in transmittances which differ by more than 0.10. Except for measurements made with filter 50, differences of greater than 0.10 are associated with the data from 9 November. Table 6 show the calculated standard deviations of these differences for each data run.

For the limited meteorological conditions (humidities between 270 and 530 Pa [2 and 4 torr] with visibilities between 50 and 100 km) the results of this comparison indicate that the two types of measurement techniques show an overall standard deviation in measured transmittance of 0.06.

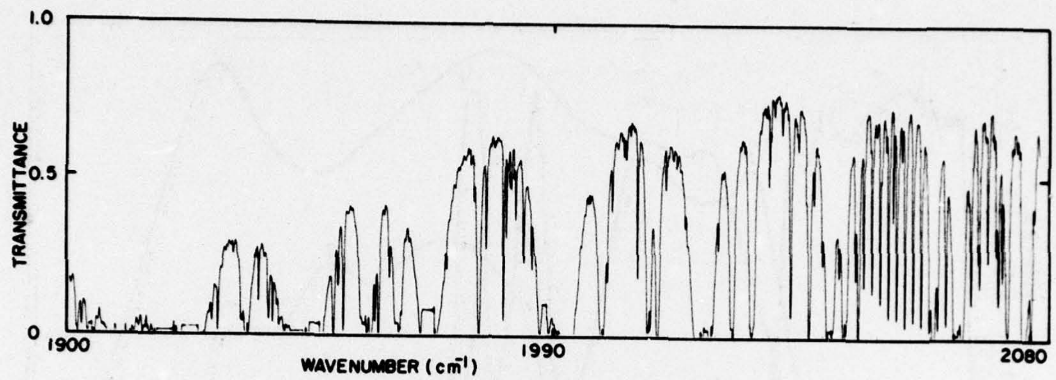


(a) Filters 01 through 07

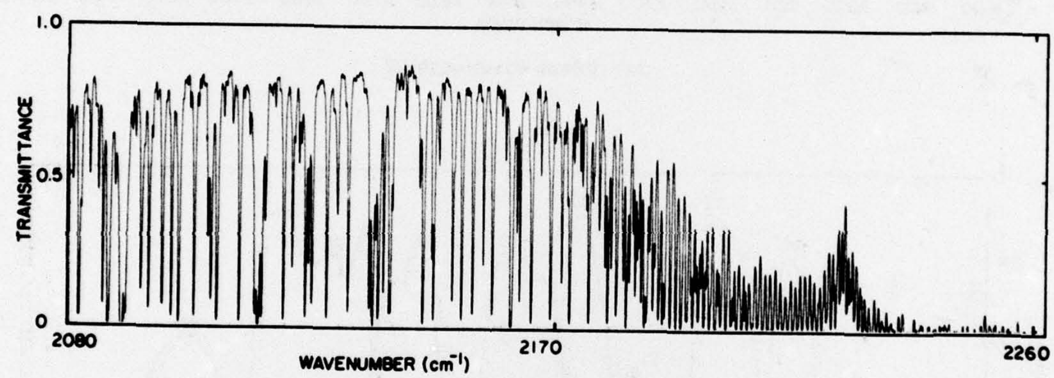


(b) Filters 10 through 80

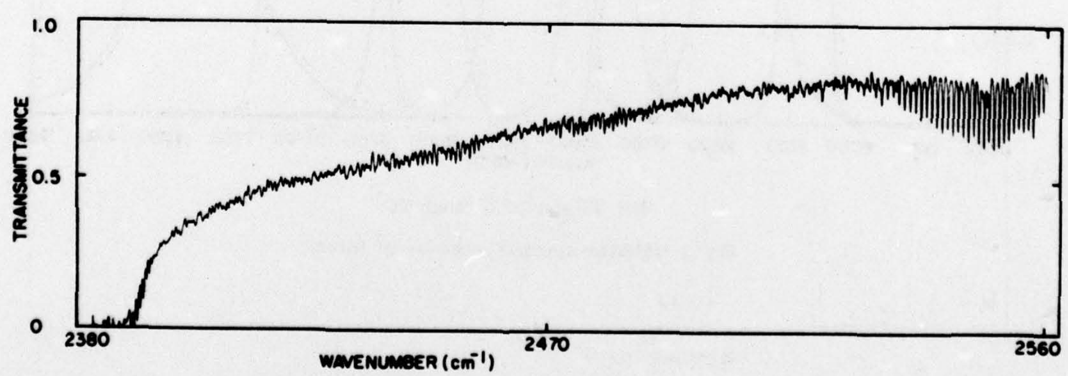
Fig. 1—Relative spectral response of filters



(a) 1900 to 2080 cm^{-1}

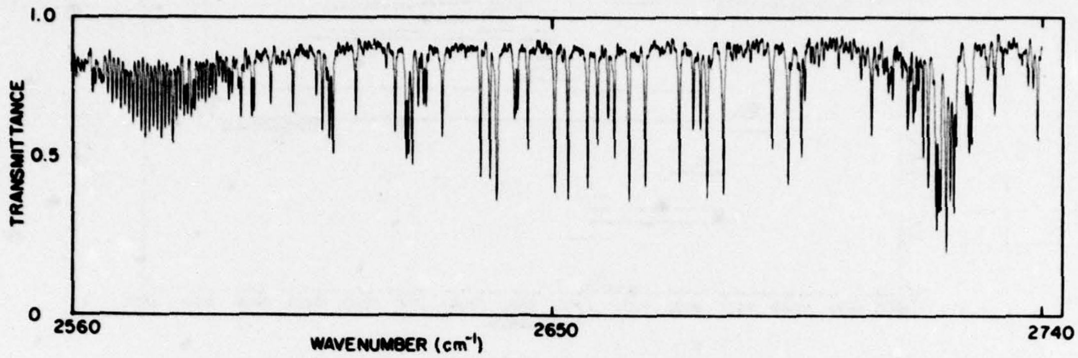


(b) 2080 to 2260 cm-1

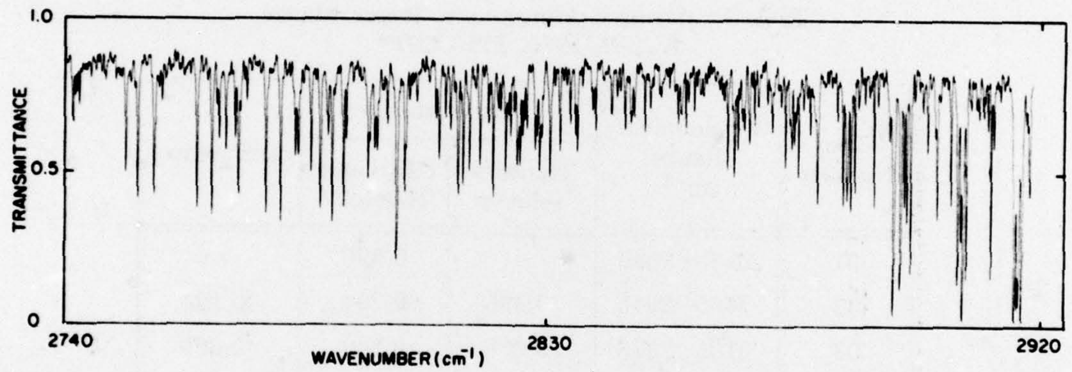


(c) 2380 to 2560 cm^{-1}

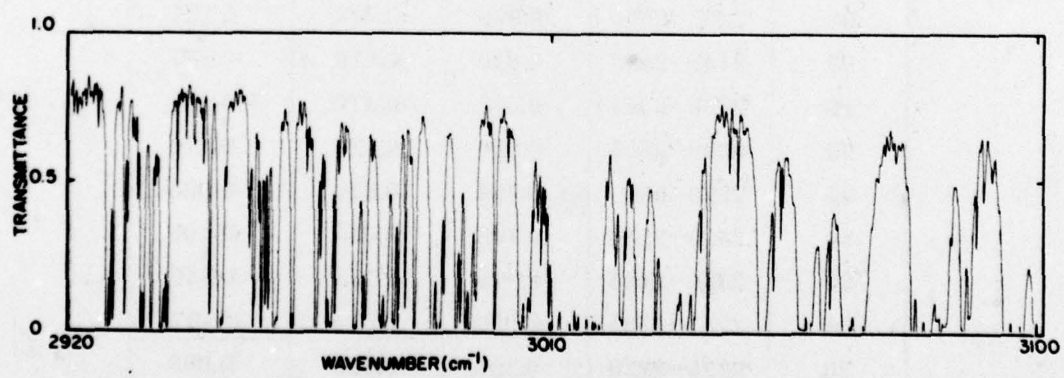
Fig. 2—Laser-calibrated high-resolution atmospheric-transmission spectrum recorded on 76 NOV 09 at 1700 (S042A).



(d) 2560 to 2740 cm^{-1}



(e) 2740 to 2920 cm^{-1}



(f) 2920 to 3100 cm^{-1}

Fig. 2 (Continued)—Laser-calibrated high-resolution atmospheric-transmission spectrum recorded on 76 NOV 09 at 1700 (S042A).

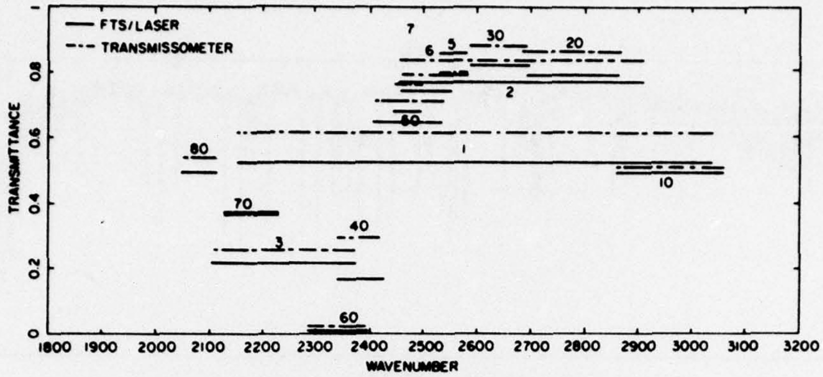


Fig. 3—Comparison of high-resolution FTS results with low-resolution transmissometer measurements recorded on 76 NOV 09 from 1645 to 1725

Table 1—Measured Atmospheric Transmittance, Nov. 9, 1976, 1115 EST*

Filter Number	Wavenumber Range (cm^{-1})	Transmittance		Difference
		Transmissometer	FTS/Laser (S040A)	
01	2155–3035	—	0.520	—
02	2465–2910	0.890	0.764	0.126
03	2105–2375	0.288	0.233	0.055
04	1835–2105	0.359	0.304	0.055
05	2535–2580	0.917	0.790	0.127
06	2455–2550	0.868	0.742	0.126
07	2445–2495	0.816	0.679	0.137
10	2865–3055	0.585	0.479	0.106
20	2690–2865	0.954	0.780	0.174
30	2585–2695	0.754	0.819	-0.065
40	2405–2540	0.748	0.645	0.103
50	2340–2425	0.319	0.173	0.146
60	2285–2385	0.000	0.015	-0.015
70	2125–2230	0.399	0.396	0.003
80	2050–2115	0.609	0.540	0.069

*Air temperature: 4.0° C; humidity: 270Pa(2.0 torr); path length: 5.1 km.

Table 2—Measured Atmospheric Transmittance, Nov. 9, 1976, 1700 EST*

Filter Number	Wavenumber Range (cm^{-1})	Transmittance		Difference
		Transmissometer	FTS/Laser (S042A)	
01	2155—3035	0.616	0.523	0.093
02	2465—2910	0.838	0.773	0.065
03	2105—2375	0.257	0.217	0.040
04	1835—2105	0.317	0.267	0.050
05	2535—2580	0.857	0.793	0.064
06	2455—2550	0.792	0.744	0.048
07	2445—2495	0.770	0.680	0.090
10	2865—3055	0.516	0.498	0.018
20	2690—2865	0.868	0.794	0.074
30	2585—2695	0.881	0.822	0.059
40	2405—2540	0.712	0.647	0.065
50	2340—2425	0.294	0.169	0.125
60	2285—2385	0.023	0.006	0.017
70	2125—2230	0.368	0.370	-0.002
80	2050—2115	0.538	0.493	0.045

*Air temperature: 4.0° C; humidity: 310Pa (2.3 torr); path length: 5.1 km.

Table 3—Measured Atmospheric Transmittance
Nov. 10, 1976, 1130 EST*

Filter Number	Wavenumber Range (cm^{-1})	Transmittance		Difference
		Transmissometer	FTS/Laser (S043A)	
01	2155—3035	0.550	0.495	0.055
02	2465—2910	0.730	0.735	-0.005
03	2105—2375	0.220	0.203	0.017
04	1835—2105	0.210	0.200	0.010
05	2535—2580	0.770	0.774	-0.004
06	2455—2550	0.705	0.734	-0.029
07	2445—2495	0.680	0.676	0.004
10	2865—3055	0.400	0.437	-0.037
20	2690—2865	0.710	0.742	-0.032
30	2585—2695	0.740	0.777	-0.037
40	2405—2540	0.650	0.643	0.007
50	2340—2425	0.290	0.174	0.116
60	2285—2385	0.023	0.005	0.018
70	2125—2230	0.320	0.349	-0.029
80	2050—2115	0.415	0.433	-0.018

*Air temperature: 14.0° C; humidity: 530Pa(4.0 torr); path length: 5.1 km.

Table 4—Measured Atmospheric Transmittance
Nov. 10, 1976, 1250 EST*

Filter Number	Wavenumber Range (cm^{-1})	Transmittance		Difference
		Transmissometer	FTS/Laser (S044A)	
01	2155—3035	0.540	0.499	0.041
02	2465—2910	0.720	0.743	-0.023
03	2105—2375	0.210	0.198	0.012
04	1835—2105	0.220	0.198	0.022
05	2535—2580	0.745	0.775	-0.030
06	2455—2550	0.730	0.732	-0.002
07	2445—2495	0.680	0.675	0.005
10	2865—3055	0.410	0.448	-0.038
20	2690—2865	0.710	0.756	-0.046
30	2585—2695	0.740	0.785	-0.045
40	2405—2540	0.640	0.643	-0.003
50	2340—2425	0.280	0.174	0.106
60	2285—2385	0.023	0.008	0.015
70	2125—2230	0.310	0.340	-0.030
80	2050—2115	0.420	0.424	-0.004

*Air temperature:14.0°C; humidity:470Pa(3.5 torr); path length:5.1 km.

Table 5—Measured Atmospheric Transmittance, Nov. 11, 1976, 1620 EST*

Filter Number	Wavenumber Range (cm^{-1})	Transmittance		Difference
		Transmissometer	FTS/Laser (S049A)	
01	2155–3035	0.550	0.489	0.061
02	2465–2910	0.740	0.731	0.009
03	2105–2375	0.225	0.196	0.029
04	1835–2105	0.200	0.208	-0.008
05	2535–2580	0.760	0.763	-0.003
06	2455–2550	0.730	0.717	0.013
07	2445–2495	0.670	0.656	0.014
10	2865–3055	0.420	0.437	-0.017
20	2690–2865	0.770	0.745	0.025
30	2585–2695	0.780	0.777	0.003
40	2405–2540	0.670	0.625	0.045
50	2340–2425	0.290	0.164	0.126
60	2285–2385	0.040	0.006	0.034
70	2125–2230	0.320	0.335	-0.015
80	2050–2115	0.460	0.430	0.030

*Air temperature: 8.5°C; humidity: 470Pa(3.5 torr); path length: 5.1 km.

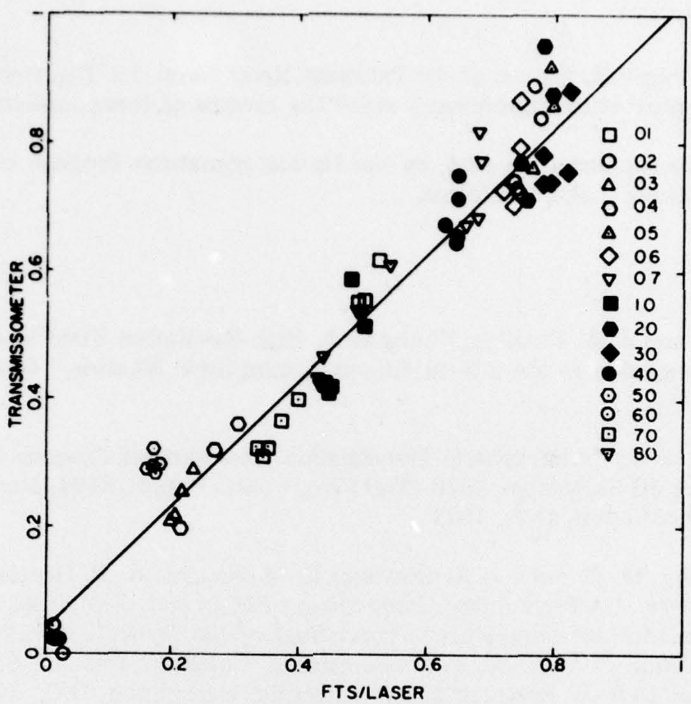


Fig. 4—Comparison between high-resolution FTS/laser results and low-resolution transmissometer measurements covering all five measurement periods.

Table 6—Standard Deviation of Measured Transmittances for Each Run

Date	Time	Standard Deviation
9 Nov	1115	0.105
9 Nov	1700	0.065
10 Nov	1130	0.039
10 Nov	1250	0.038
11 Nov	1620	0.042

ACKNOWLEDGMENTS

The authors thank M. Haines of the Patuxent River Naval Air Test Center for the local logistical support which significantly aided the success of these experiments.

This work was supported, in part, by the Optical Signatures Program of the Naval Weapons Center, China Lake, California.

REFERENCES

1. K. M. Haught and J. A. Dowling, "Long-Path, High-Resolution Field Measurement of Absolute Transmission in the 3.5- to 4.0-μm Atmospheric Window," *Optics Letters* 1, 121-123 (1977).

2. T. H. Cosden, et al., "Atmospheric Transmission Measurement Program Report for 1 July Through 30 September 1976 (TQ1976)," NRL Report 8104, Naval Research Laboratory, Washington, D.C., 1977.

3. R. J. Bergemann, M. C. Sola, J. A. Dowling, K. M. Haught, R. F. Horton, J. L. Walsh, and R. E. Roberts, "A Preliminary Comparison of High and Low Resolution Atmospheric Transmission Measurements," *Proceedings of the Optical-Submillimeter Atmospheric Propagation Conference*, Colorado Springs, Colorado, Dec. 1976, Vol. 1, Office of the Director, Defense Research and Engineering, Washington, D.C., 1977.

4. J. A. Dowling, et al., "Atmospheric Transmission Measurement Program and Field Test Plan," NRL Report 8059, Naval Research Laboratory, Washington, D.C., 1977.

5. J. R. Moulton and F. M. Zweibaum, "Atmospheric Transmissometer and Radiometer for E-O Sensor Field Evaluation and Model Validation," in *Methods for Atmospheric Radiometry*, Proceedings of SPIE Annual Symposium, San Diego, California, Aug. 1976, Society of Photo-Optical Instrumentation Engineers, 1976, Vol. 91, pp. 30-38.

6. M. C. Sola and R. J. Bergemann, "Multi-Spectral Propagation Measurements Through Snow," in *Optical Propagation Through Turbulence, Rain, and Fog*, a digest of papers presented at OSA Topical Meeting, Boulder, Colorado, Aug. 1977, Optical Society of America, Washington, D.C., 1977.

7. K. M. Haught and D. M. Cordray, "Long-Path, High-Resolution Atmospheric Transmission Measurements: Comparison with LOWTRAN 3B Predictions," *Applied Optics* 17, 2668-2670 (1978).